# Planetary Defense team project: READI (Roadmap for EArth Defense Initiatives)

Alaa Hussein, Anushree Soni, Bora Aliaj, Carlos Entrena, Chanwoo Lee, Doron Shterman, Fernando Gonzalez, Hugh Byrne, Idriss Sisaid, Jackelynne Silva, James McCreight, Jessica Reinert, Jonathan Faull, Lars Hoving, Laura Bettiol, Louis Neophytou, Marianne Girard, Naama Glauber, Nicholas Strzalkowski, Nikola Schmidt, Oshri Rozenheck, Parker Stratton, Rémi Gourdon, Shajiha Meeran, Shangrong Ouyang, Shitao Ji, Toby Call, Susanne Peters, Tihomir Dimitrov, Shrrirup Nambiar, Umang Parikh, Yunjun Yang, Yuxian Jia, Zheng Fang

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# READI

## Roadmap for EArth Defense Initiatives

## EXECUTIVE SUMMARY

INTERNATIONAL SPACE UNIVERSITY

SSP2015

CONTEXT

## INTRODUCTION

Life on Earth is threatened by many different hazards, from both internal and external agents. One significant threat has long been beyond the reach of our species to influence. High energy impacts from cosmic bodies, such as asteroids and comets, represent a range of threats from minimal localized damage to extinction level events. 65 million years ago, the last major extinction event occurred when an asteroid, approximately 10 km in diameter, collided with Earth. While our planet is constantly bombarded by small objects, recent events have led experts to believe the threat from hazardous asteroids and comets is greater than we previously thought. Advances in technology offer the ability for humanity to ensure the survival of our species on Earth. We must now take an active role in protecting our planet and the biosphere from the very real threat of asteroid and cometary impacts.

## MISSION STATEMENT

The READI Project proposal plans to develop and implement components of an Planetary Defense program for detection and mitigation of asteroid and comet threats with short warning periods, consisting of ground and space segments that include technologies, global cooperation, and public awareness.

## THE PROBLEM

In our approach to the challenges of Planetary Defense, we considered protection against both asteroids and comets. We chose mid-range sized asteroids and comets because they represent the most unpredictable threat. Larger objects are almost completely known, smaller objects do not pose a threat, and mid-range objects are difficult to detect, yet pose a substantial hazard. We constrained ourselves to two years from time of detection until impact because the current discussion on the topic mainly focuses on long-term threats. Current technology fails to meet the challenges these conditions present, therefore we explored technologies and methods possible by 2030. We divided Planetary Defense into five elements that we consider essential for a complete roadmap: detection and tracking, outreach and education, global collaboration, deflection techniques, and evacuation and recovery.

*For more details please refer to the READI Project report at

## THE SCENARIOS

We rely on graphic storytelling to describe how the READI Project recommendations would apply in a potential future impact scenario. We use a cometary threat since comets are less frequently discussed in the literature and intrinsically more challenging than asteroids. We show how the scenario would develop in the optimistic case in which our recommendations were followed and the world was prepared, as well as in a pessimistic case in which limited preparations were made. These contrasting cases are realistically based on possible futures, and we present them in parallel (optimistic on the left and pessimistic on the right pages) to emphasize the need for preparation before the appearance of a threat, and to engage a wide audience on the topic of Planetary Defense.

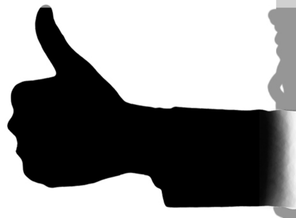
## And the story begins

The year is **2030** and humanity is about to face a **threat** on a scale never seen before.

On 1 January, a new object is observed on the outer edges of the Solar System with an apparent Earth crossing orbit: it is a **comet!** A comet that will take the official name of **P/2030A1(Madhu), aka Madhusa**. Preliminary analysis shows only **two** years until impact.

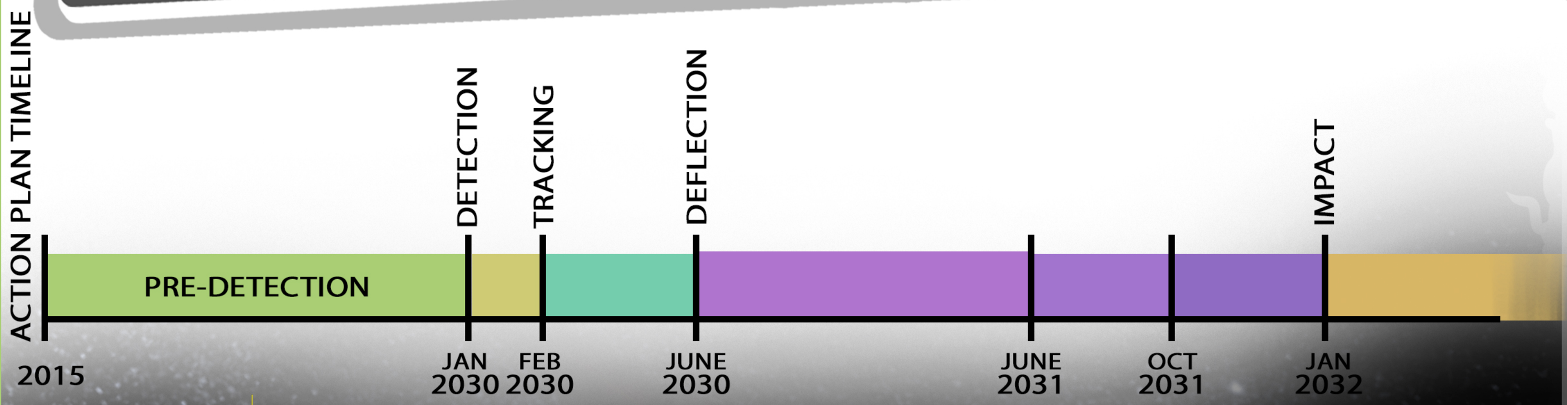
**COMET P/2030A1:MADHU - AT DISCOVERY**
**Time to impact:** 2 years
**Threat level:** Low, 0.1% chance for impact
**Size:** 500 m
**Impact location estimate:** Unknown

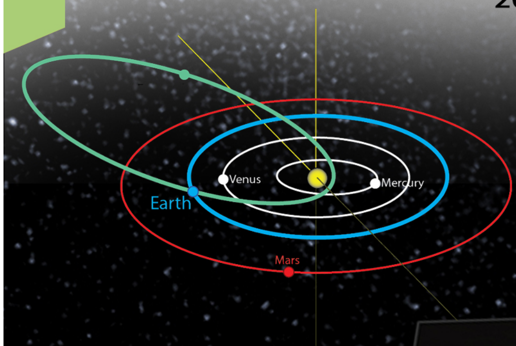
DETECTION - OPTIMISTIC



OPTIMISTIC SCENARIO

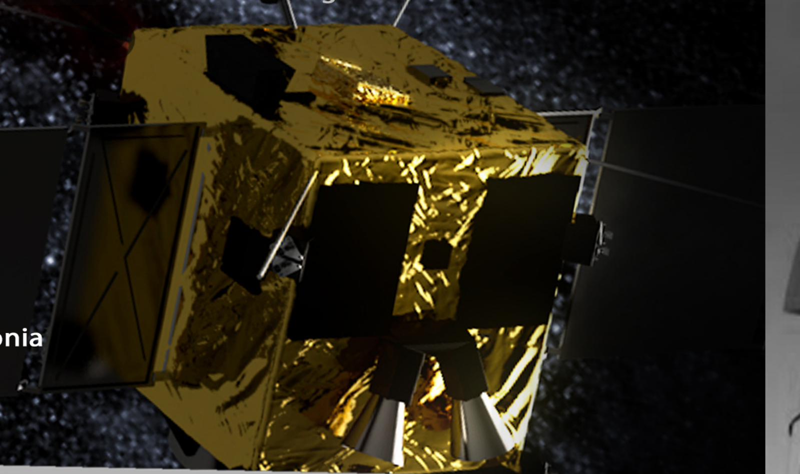
Between **2015** and **2030**, humanity becomes increasingly concerned about natural disasters, and effective outreach programs bring near Earth objects (NEOs) into the global consciousness and dialog. A significant boost in Planetary Defense preparedness came from a shift in governmental risk assessment attitude. A continued expansion of humanity's presence in Space, combined with effective public outreach, reinforced the responsibility of governments to protect their citizens from cosmic threats.




COMET ORBIT:
Semi-major axis: **34.2 AU**
Period: **200 years**
Perihelion: **0.27 AU**
Aphelion: **68.15 AU**
Eccentricity: **0.992**

AT DETECTION:
Distance Sun-comet: **8.15 AU**
Magnitude: **21.2**

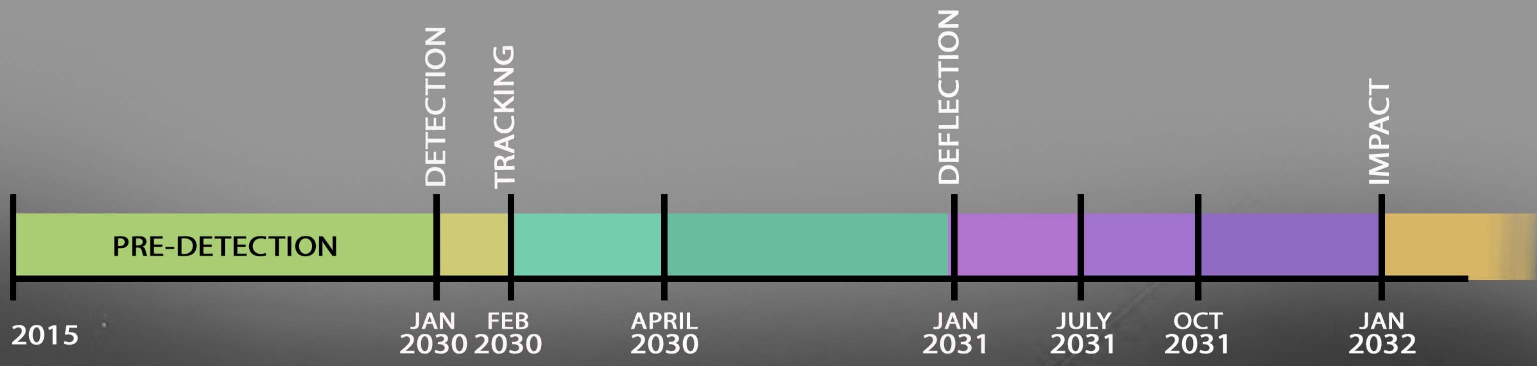


COMET CHARACTERISTICS
SIZE: **500m**
DENSITY: **0.6g/cm3**
Composition: **mainly ICE (water, methane, ammonia and loose rocks)**

After discovery on 1 January comet P/2030A1(Madhu), nicknamed **MADHUSA**, became the focus of a global space and ground-based telescope network, including systems at the Earth-Sun Lagrange points **L1**, **L4**, and L5. Use of both optical and **infrared sensors** quickly characterized Madhusa (see comet characterstics). Within a month, the probability of Madhusa colliding with Earth increased from 0.1% to 50% with an anticipated impact ellipse encompassing a large area in the southern hemisphere. Information on the threat quickly travelled through global networks from the International Asteroid Warning Network to the UN Security Council (UNSC). The UNSC activated the Mitigation Action Group to prepare for a possible deflection mission.

## PESSIMISTIC SCENARIO

Shortly after its completion in 2016, the Rosetta mission was quickly forgotten and the resulting lack of public support led to the cancelation of NASA's Asteroid Retrieval Mission, hindering asteroid exploration efforts. In the fifteen years leading up to **2030**, governments across the world became increasingly shortsighted. Due to the lack of Planetary Defense initiatives and minimal outreach education, there was limited advancement in humanity's capacity to respond to any serious cosmic threats.




Despite the discovery on 1 January 2030 of Madhusa and its 0.1% chance of colliding with Earth, the global community did little in response. Without dedicated telescopes, astronomers were slow to understand Madhusa's trajectory. It took three months to gather sufficient data to increase the probability of impact to 50%. Governments and populations were shocked by the threat, yet many remained uninformed of the danger. The combination of shock and lack of preparation prevented the development of an effective and timely global effort to deal with Madhusa.


DETECTION - PESSIMISTIC

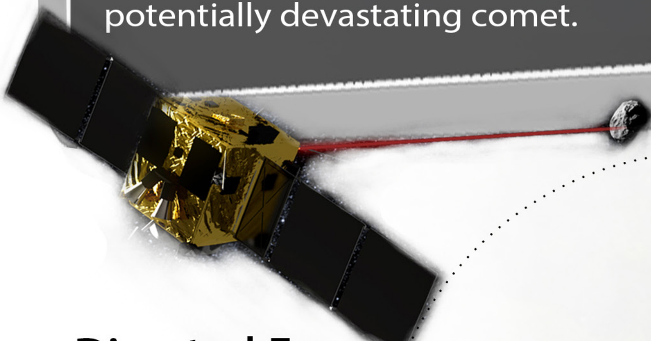
DEFLECTION - OPTIMISTIC

The Mitigation Action Group (MAG), already well informed of the situation, immediately initiated the Synchronized Earth Protection Plan (SEPP).

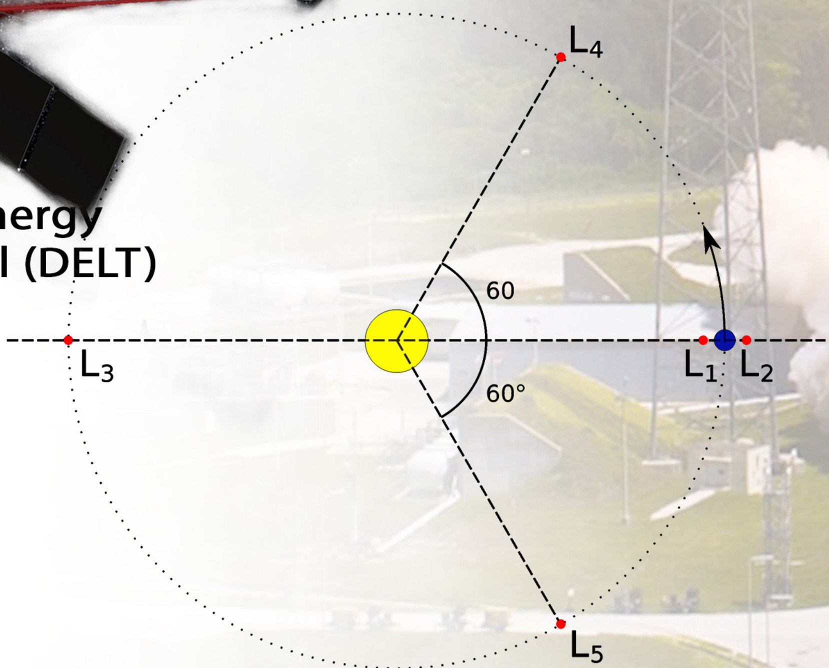
PHASE 1:
Activating the Directed Energy Laser Terminals (DELTs) placed in Earth-Sun Lagrange points L4 and L5 back in 2027 after an unknown asteroid narrowly missed Earth. The directed energy from both DELTs was focused on Madhusa and slowly but efficiently caused ablation that created thrust.

PHASE 2:
After seven months of continuous ablation, the chances of collision were reduced to 10%, but the uncertainty of Madhusa's perihelion passage left experts and leaders deeply concerned. The MAG, in partnership with the UN Security Council (UNSC) overcame considerable opposition to launch a Hypervelocity Comet Impactor Vehicle (HCIV) to ensure a successful deflection.

PHASE 3:
Three months before the predicted impact but before its perihelion passage, the HCIV reached Madhusa and detonated its 25-megaton nuclear device. Observations confirmed that the combination of the DELTs and HCIV successfully reduced the probability of impact to just 0.01%. Given the potential for fragments to still impact Earth, the MAG and UNSC authorized the use of ballistic defense domes to intercept any incoming debris. The SEPP was a complete success in deflecting a potentially devastating comet.



Directed Energy Laser Terminal (DELT)




Earth-Sun Langrange Points



A year after Madhusa's detection, global collaboration remained elusive, largely as a result of political ambiguity, disagreements, and lack of information. Unwilling to wait longer, India and the US developed a secret plan to modify an Indian Geosynchronous Satellite Launch Vehicle to carry an American nuclear device. The vehicle launched successfully in July 2031, despite a politically divided global community. As the vehicle approached its final phase near Madhusa's perihelion, it struggled to maintain its intercept course. Errors in navigation resulted in the payload detonating several kilometers from Madhusa. The nuclear blast resulted in some ablation and thrust that slightly altered Madhusa's trajectory. The global community awaited news of the mission's success. As Madhusa came back into view, it became clear that the mission had failed to deflect the comet; it only shifted impact location. Madhusa was headed for the border between France and Germany and would impact with a velocity of 42 km/s, releasing 4 Gigatons of energy (80 times the largest nuclear bomb ever detonated). Riots, civil disorder, and global mistrust resulted from the failed secret mission. With the impending impact European nations, with the approval of the UNSC, decide to use ballistic missile defense systems as a final defense against Madhusa.

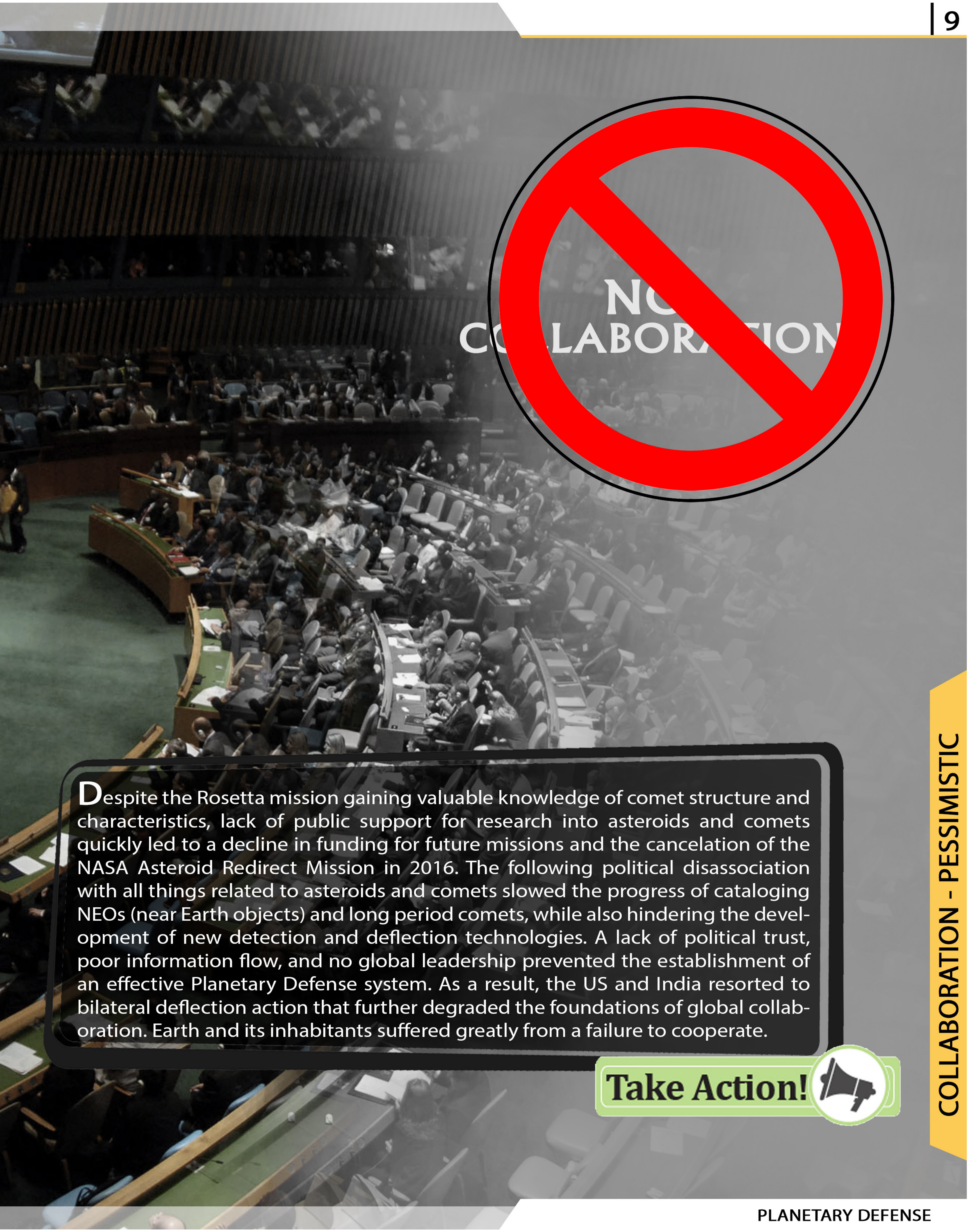
DEFLECTION - PESSIMISTIC

COLLABORATION - OPTIMISTIC

In the years leading up to 2030, policy and decision makers developed an in-depth understanding of the threats from asteroids and comets. Public opinion following a near miss by an asteroid in 2022 drove decision makers to increase their efforts toward Planetary Defense. The transition in thought processes from vague threats popularized in movies to a proactive defense architecture saved countless lives and prevented immense environmental damage in 2032. The success of the global collaboration between Madhusa's discovery in 2030 and its deflection in 2032 was attributed to a robust information-sharing infrastructure, pre-planned responses, Responsibility to Defend Earth, and rapid trust-based decision making.

Mitigation Action Group (MAG)
The purpose of the MAG is to recommend action to the UNSC and, upon approval from the UNSC, oversee the implementation of those actions from the expert perspective.

Responsibility to Defend Earth (R2DE)
The R2DE is a proposed norm (extrapolated from the existing Responsibility to Protect) that humanity has the responsibility to defend the Earth against threats such as comets and asteroids. This norm would be used to justify actions in the area of Planetary Defense.




Despite the Rosetta mission gaining valuable knowledge of comet structure and characteristics, lack of public support for research into asteroids and comets quickly led to a decline in funding for future missions and the cancelation of the NASA Asteroid Redirect Mission in 2016. The following political disassociation with all things related to asteroids and comets slowed the progress of cataloging NEOs (near Earth objects) and long period comets, while also hindering the development of new detection and deflection technologies. A lack of political trust, poor information flow, and no global leadership prevented the establishment of an effective Planetary Defense system. As a result, the US and India resorted to bilateral deflection action that further degraded the foundations of global collaboration. Earth and its inhabitants suffered greatly from a failure to cooperate.

Take Action!

OUTREACH - OPTIMISTIC

Planetary Defense education and outreach campaigns began in 2015, targeting students and youngsters aged 6-15. Children, as the future scientists, engineers, storytellers and policy makers, were the ideal target audience to increase awareness and preparedness of the threat from asteroids and comets. Planetary Defense themes based around the mascots Ash and Pho were incorporated in various popular computer games and other media to increase the knowledge, interest, and enthusiasm about asteroids and comets among the general public. Interest among youngsters helped to inform their parents and in turn the policy makers. The flow of Planetary Defense information and knowledge, originating with the education campaigns, directly led to the creation of the global political structures that prepared and enacted the successful deflection campaign.

Ash

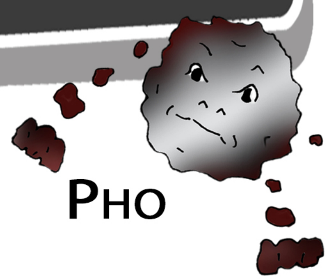
Development of Planetary Defense scenario in Kerbal Space Program

Smartphone Game Application

Educational Comics

Outreach Video: To create awareness among the general public and also depict the current technological and political readiness level for Planetary Defense.

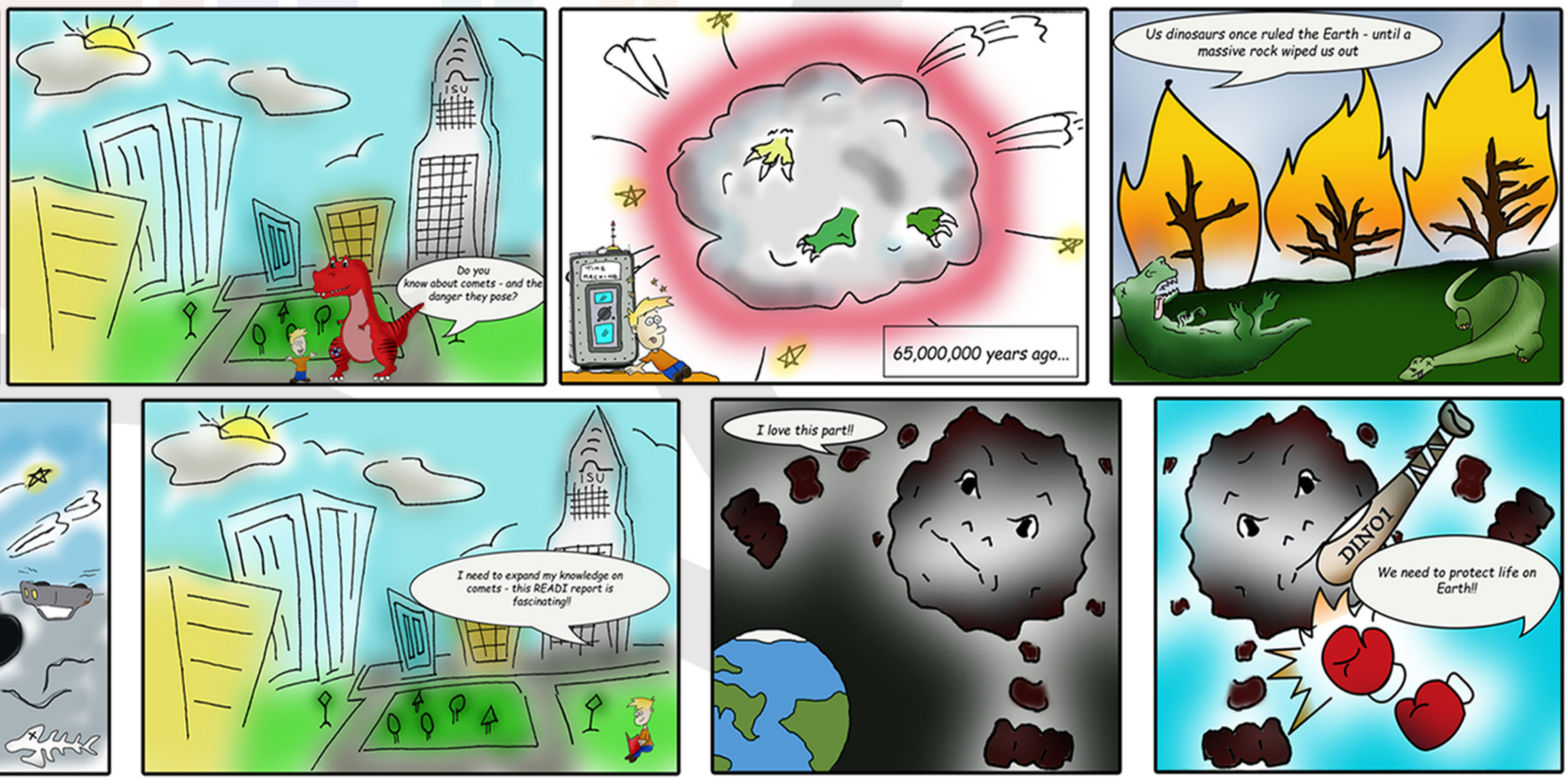
Mascots: Ash and Pho to create enthusiasm for Planetary Defense among the younger generation



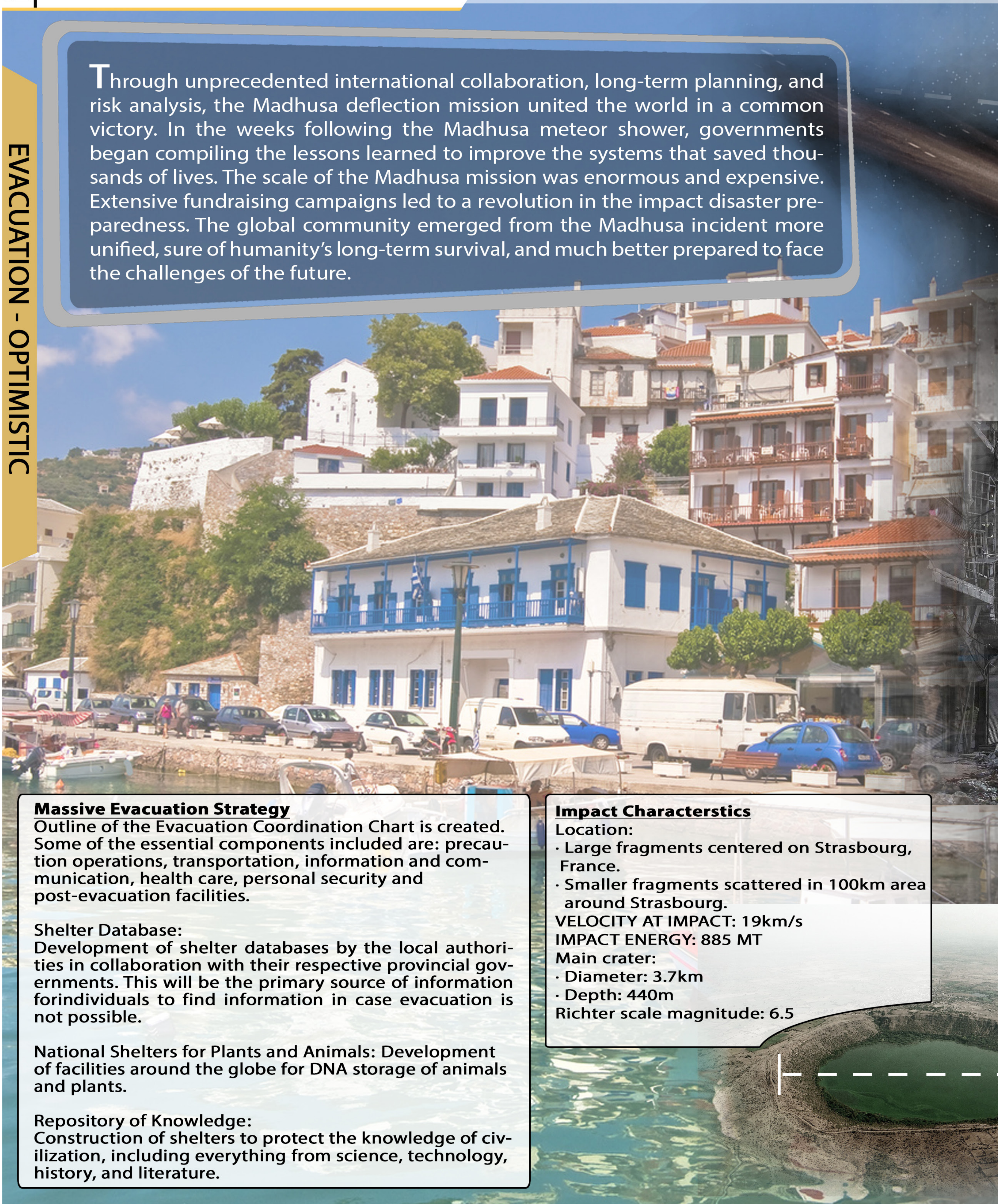
Pho

In 2015, some education and outreach programs were initiated, but due to a lack of enthusiasm the campaign failed to meet its objective and was rendered ineffective. From 2015 to 2030 no prominent education or outreach programs on asteroids or comets succeeded, which resulted in little political, scientific, or public attention on Planetary Defense. The lack of education on cosmic impacts created an environment in 2030 in which the global community was unable to accept and act in response to the Madhusa discovery. As a consequence, policy makers were less likely to implement Planetary Defense measures.

## THE HISTORY OF THE DINOSAURS' EXTINCTION



EVACUATION - OPTIMISTIC



Through unprecedented international collaboration, long-term planning, and risk analysis, the Madhusa deflection mission united the world in a common victory. In the weeks following the Madhusa meteor shower, governments began compiling the lessons learned to improve the systems that saved thousands of lives. The scale of the Madhusa mission was enormous and expensive. Extensive fundraising campaigns led to a revolution in the impact disaster preparedness. The global community emerged from the Madhusa incident more unified, sure of humanity's long-term survival, and much better prepared to face the challenges of the future.

**Massive Evacuation Strategy**

Outline of the Evacuation Coordination Chart is created. Some of the essential components included are: precaution operations, transportation, information and communication, health care, personal security and post-evacuation facilities.

Shelter Database:
Development of shelter databases by the local authorities in collaboration with their respective provincial governments. This will be the primary source of information forindividuals to find information in case evacuation is not possible.

National Shelters for Plants and Animals: Development of facilities around the globe for DNA storage of animals and plants.

Repository of Knowledge:
Construction of shelters to protect the knowledge of civilization, including everything from science, technology, history, and literature.

**Impact Characterstics**

Location:
- Large fragments centered on Strasbourg, France.
- Smaller fragments scattered in 100km area around Strasbourg.

VELOCITY AT IMPACT: 19km/s
IMPACT ENERGY: 885 MT
Main crater:
- Diameter: 3.7km
- Depth: 440m

Richter scale magnitude: 6.5




First fragments then the main body of Madhusa impacted across the French-German border, creating a seismic event of 6.5 on the Richter scale. The corresponding shockwaves affected an area of more than 100 km in diameter. Air bursts smashed into the impact zone causing massive damage. Dozens of kilometers in diameter were completely devastated. The whole event only lasted several minutes but the loss of life was unparalleled and the long-term environmental and economic consequences of Madhusa would last for generations. Despite knowledge of the impact site, first responders were slow to mobilize causing the death toll to rise in the hours and days following the impact. Global support and emergency infrastructures were insufficient to handle the scale of the disaster. As the situation grew more and more dire the death toll rapidly increased. Many of the deaths were due to lack of preparation rather than the impact. The regrets of indecision began to set in as governments started blaming each other for complacency. It would take decades for nations and the global economy to return to its pre-Madhusa status quo. Unfortunately, mistrust and lack of accountability prevented the global community from learning its lessons.

## CONCLUSION

The preceding narrative explores the potential of the READI Project's main elements for a complete Planetary Defense system architecture. The world is currently not prepared to protect itself from an impact threat with a short warning period. We believe that the implementation of such a Planetary Defense system should be a priority for humanity. The READI Project represents a roadmap for our survival, and demonstrates that current advances in technology and operations allow such a capability to be deployed in a phased approach. The time for action is now.

**2015**

Southern hemisphere coverage

Game concept developed

Hipervelocity intercept vehicles (HCIV) developed

Mitigation Action Group (MAG) Roadmap created and approved by UN Security Council

Development of Planetary Defense technology overseen by MAG

ASH used by space agencies for outreach campaigns

**2020**

Improved impact disaster preparedness and damage assessment

Dedicated infrared space telescope deployed

Badge for Boy Scouts implemented

Deployment, but not testing of PD technology approved by UNSC

National expedient shelter competitions

**2025**

Directed Energy Laser Terminals (DELT) developed and launched

For more details please refer to the READI Project report at https://isulibrary.isunet.edu/opac/

Comet detected

Probability of impact 50% after 1 month

2030

Use of DELT against comet approved by UN MAG

Public informed of comet impact in 2 years with mascot campaign

Comet engaged by DELT system engages target

Shelters database published

Deployable shelters manufacturing begin

Use of HCIV approved by UN MAG

Impact chance reduced to 10% and HCIV launched in first opportunity

2031

Public kept calm with transparent information flow

Evacuation task forces deployed and evacuation measurements put in place

2032

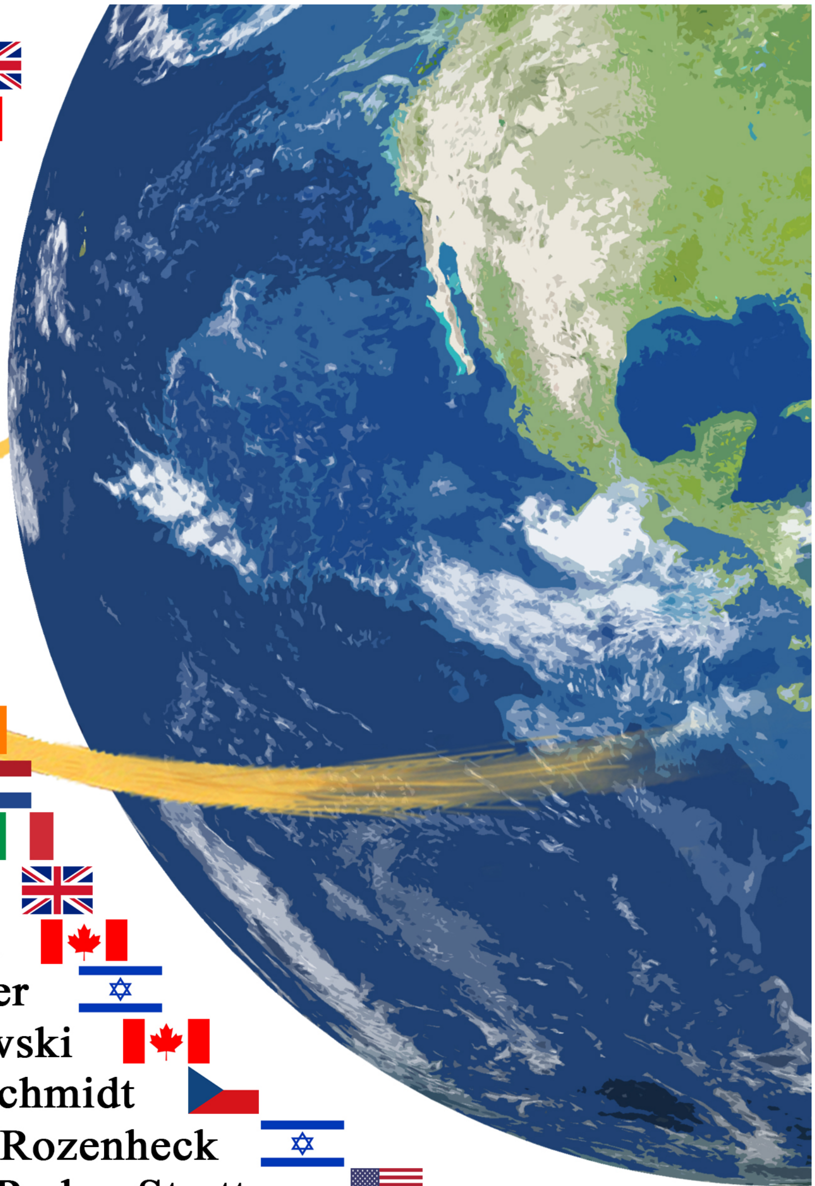
Succesful deflection confirmed

Increased transparenc and confidence amon nations created as a result of successful global collaboration

Focus placed on human settlement of space to ensure survival

## RECOMMENDATIONS

- Dedicated space-based infrared Telescopes
- Southern hemisphere coverage
- Improved detection algorithms
- Validation of nuclear and directed energy systems
- Space demonstration of directed energy
- Incorporation of ballistic missile defense technology
- Establishment of Right to Defend Earth
- Governance body for deflection infrastructure
- Promotion of mascots Ash and Pho
- Development of life-long learning plan
- Transparent information flow
- Inclusion of impacts in disaster preparedness
- Creation of national shelter databases
- Development of recovery strategy



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## Roadmap for EArth Defense Initiatives

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